SPECIFICATION

TO ALL WHOM IT MAY CONCERN:

BE IT KNOWN THAT WE, Yoshikazu Kanazawa, a citizen of Japan residing at Kawasaki, Japan and Seiki Kuroki, a citizen of Japan residing at Higashimorokata, Japan have invented certain new and useful improvements in

PLASMA DISPLAY DEVICE

of which the following is a specification : -

TITLE OF THE INVENTION

PLASMA DISPLAY DEVICE

BACKGROUND OF THE INVENTION

1. Field of the Invention

The present invention generally relates to flat-panel display devices, and more particularly to a plasma display device.

A plasma display device is a flat-panel display device of a light-emitting type that displays picture information by selectively inducing discharges in a gas filled between a pair of glass substrates.

It is important for the plasma display device to increase resolution and reduce power consumption at the same time.

2. Description of the Related Art

FIG. 1 is a diagram showing a basic structure of a conventional common plasma display device 10. A structure similar to this is disclosed in Japanese Laid-Open Patent Application No. 2000-195431.

The plasma display device 10 is basically defined by a display panel 11 and first through third driving circuits 12A through 12C that cooperate with the display panel 11. The display panel 11 includes first discharge electrodes X_1 through X_m and second discharge electrodes Y_1 through Y_m that are alternately arranged parallel to each other and extend in the X direction of FIG. 1. Further, the display panel 11 includes address electrodes Z_1 through Z_n that extend in the Y direction of FIG. 1 to intersect the first and second discharge electrodes X_1 through X_m and Y_1 through Y_m. The first discharge electrodes X_1 through X_m, the second discharge electrodes Y_1 through Y_m, and the address electrodes Z_1 through Z_n

are selectively activated by the first through third driving circuits 12A through 12C, respectively.

For instance, an address voltage is applied between a selected one of the first discharge electrodes X_1 through X_m (X_2 in FIG. 1) and a selected one of the address electrodes Z_1 through Z_n (Z_4 in FIG. 1), so that a discharge is started between the first discharge electrodes X_2 and the address electrode Z_4. Next, by applying a discharge-sustaining voltage between the first discharge electrodes X_2 and the adjacent second discharge electrode Y_2 by the driving circuits 12A and 12B, a discharge is started between the first discharge electrodes X_2 and the second discharge electrode Y_2 in a display cell selected by the address electrode Z_4. The discharge is maintained while the selected display cell is activated.

It is required for such a plasma display device to increase resolution by narrowing pitches between electrodes and reduce power consumption at the same time.

FIG. 2 is a sectional view of the conventional plasma display panel 11, whose type is referred to as an ALIS (Alternate Lighting of Surfaces) type, taken along the Y direction of FIG. 1.

The display panel 11 of FIG. 2 is defined by glass substrates 11A and 11B opposed to each other, and a discharge gas is filled between the glass substrates 11A and 11B.

The glass substrate 11A may be referred to as a front or display-side substrate facing a viewer of the display panel 11, and the glass substrate 11B may be referred to as a rear substrate provided across the glass substrate 11A from the viewer.

More specifically, the glass substrate 11A has the first and second discharge electrodes X_1

through X_m and Y_1 through Y_m alternately arranged with the same pitch on its side opposing the glass substrate 11B. The glass substrate 11B has the address electrodes Z_1 through Z_n formed on its side opposing the glass substrate 11A. The first and second discharge electrodes X_1 through X_m and Y_1 through Y_m are formed of a transparent conductive film of ITO ($In_2O_3 \cdot SnO_2$), and the first discharge electrodes X_1 through X_m (ITO electrodes) has low-resistance bus electrodes x_1 through x_m formed thereon, respectively. Similarly, the second discharge electrodes Y_1 through Y_m (ITO electrodes) has low-resistance bus electrodes y_1 through y_m formed thereon, respectively. On the other hand, the address electrodes Z_1 through Z_n are formed of low-resistance metal patterns to extend in a direction to cross a direction in which the bus electrodes x_1 through x_m or y_1 through y_m extend. The first and second discharge electrodes X_1 through X_m and Y_1 through Y_m and the bus electrodes x_1 through x_m or y_1 through y_m are covered with a dielectric film 11a on the glass substrate 11A, and the address electrodes Z_1 through Z_n are covered with a dielectric film 11b on the glass substrate 11B. Further, as is not shown in the drawing, fluorescent material patterns of red, green, and blue are applied and formed on the dielectric film 11b in accordance with display pixels.

In the display panel 11 of the above-described structure, discharges caused between the glass substrates 11A and 11B excite the fluorescent material patterns to produce light, which is emitted through the glass substrate 11A as indicated by arrow in FIG. 2.

FIGS. 3(A) and 3(B) are plan views of patterns of the first and second discharge electrodes X_1 through X_m and Y_1 through Y_m formed on

the glass substrate 11A in another conventional ALIS-type plasma display device including the display panel 11. The X and Y directions of FIGS. 3(A) and 3(B) correspond to those of FIG. 1.

In FIG. 3(A), the first and second discharge electrodes X_1 through X_m and Y_1 through Y_m are formed of series of repeated T-shaped ITO patterns (electrodes) XT and YT extending from longitudinal sides of the corresponding bus electrodes x_1 through x_m and y_1 through y_m on the glass substrate 11A, respectively. Each ITO pattern has a tip part T_A of a width A that extends in the extending direction of the bus electrodes x_1 through x_m or y_1 through y_m and a narrow neck part T_B connecting the tip part T_A and a corresponding one of the bus electrodes x_1 through x_m or y_1 through y_m. Each adjacent ITO patterns are arranged with a pitch corresponding to the resolution of the display panel 11, for instance, a pitch of 300 μm in FIG. 3(A), and a discharge is sustained in a gap (discharge gap) of a width g formed between each opposed ITO patterns XT and YT.

FIG. 4 is a diagram showing a structure of the glass substrate 11B of FIG. 2.

In FIG. 4, ribs 11C are formed with given pitches on the glass substrate 11B to extend in the Y direction of FIG. 1. Grooves G_1 through G_n are formed between the ribs 11C, and the address electrodes Z_1 through Z_n are formed in the corresponding grooves G_1 through G_n. Further, the address electrodes Z_1 through Z_n are covered with the dielectric film 11b in the corresponding grooves G_1 through G_n, and the fluorescent material patterns R, G, and B of red, green, and blue, respectively, are formed on the dielectric film 11b.

The glass substrate 11B of FIG. 4 is reversed to be placed on the glass substrate 11A so

that, as shown in FIG. 5, the grooves G_1 through G_n formed between the ribs 11C contain the corresponding ITO patterns XT and YT.

In the plasma display panel 11 of the above-described structure, a drive current for a discharge can be reduced by narrowing a width of the neck part T_B of each ITO pattern XT or YT, and the discharge-sustaining voltage can be decreased by increasing the width A of the tip part T_A of each ITO pattern XT or YT, or by decreasing the width g of the discharge gap.

If the plasma display panel 11 is to offer 1024×1024 resolution, letting its diagonal be 42 in., a pitch between each adjacent address electrodes Z_1 through Z_n must be set to 300 μm. However, in the case of such a high-resolution plasma display panel, where each rib 11C has a width of 60 μm and the tip part T_A of each ITO pattern XT or YT has the width A of 160 μm, each rib 11C and each ITO pattern XT or YT adjacent thereto are only slightly separated by a margin δ. Therefore, if a deviation between the positions between the glass substrates 11A and 11B exceeds the margin δ, each rib 11C, as shown in FIG. 6, overlaps the tip part T_A of each adjacent ITO pattern XT or YT, thus reducing the width A of the tip part T_A.

SUMMARY OF THE INVENTION

It is a general object of the present invention to provide a plasma display device in which the above-described disadvantage is eliminated.

A more specific object of the present invention is to provide a high-resolution and low-power-consumption plasma display device that can be produced with a good fabrication yield.

The above objects of the present invention are achieved by a plasma display device having first

and second substrates and a discharge gas filled therebetween, which plasma display device includes first and second electrodes extending parallel to each other on a first substrate, and first and second discharge electrode parts extending from the first and second electrodes, respectively, so as to oppose each other, wherein a discharge gap of a substantially constant width is formed between one of the first discharge electrode parts and one of the second discharge electrode parts, the ones opposing each other, the discharge gap being defined by first and second edge parts of the ones of the first and second discharge electrode parts, respectively, and the first and second edge parts have lengths longer than widths of the ones of the first and second discharge electrode parts, the widths being measured in directions in which the first and second electrodes extend, respectively.

According to the above-described plasma display device, at the same time that the effective length, that is, the length actually related to a discharge, of the edge part of each of the first and second discharge electrode parts is maintained so as to minimize a discharge starting voltage and a drive current for sustaining the discharge, the width of each of the first and second discharge electrode parts measured in the direction in which the first or second discharge electrode part extends can be smaller than the effective length of the edge part.

Additionally, in the above-described plasma display device, the discharge gap may have a length longer than or equal to 150 μm and shorter than 200 μm.

If the length of each of the first and second edge parts exceeds 200 μm, a discharge current increases while luminous efficacy decreases. Therefore, it is preferable to form the discharge

gap of the constant width and the length longer than or equal to 150 μm and shorter than 200 μm between the ones of the first and second discharge electrode parts.

Further, in the above-described plasma display device, the discharge gap of the constant width and the length longer than or equal to 150 μm and shorter than 200 μm is formed between the ones of the first and second discharge electrode parts, and the first and second edge parts have the lengths longer than the widths of the ones of the first and second discharge electrode parts measured in the directions in which the first and second electrode parts extend, respectively. Therefore, if a pitch between each adjacent first or second discharge electrode parts is narrowed, a sufficient margin can be secured therebetween. That is, according to the present invention, the plasma display device can be driven with a low voltage and low power consumption while eliminating a problem that some of the first and second discharge electrode parts may overlap ribs, or partition walls, formed on the second substrate because of an error in positioning the first and second substrates.

BRIEF DESCRIPTION OF THE DRAWINGS

Other objects, features and advantages of the present invention will become more apparent from the following detailed description when read in conjunction with the accompanying drawings, in which:

FIG. 1 is a block diagram showing a schematic structure of a conventional plasma display device;

FIG. 2 is a sectional view of a plasma display panel employed in the plasma display device of FIG. 1;

FIGS. 3(A) and 3(B) are diagrams for illustrating a structure of electrodes formed on a display-side substrate of the plasma display panel of FIG. 2;

FIG. 4 is a perspective view of a rear substrate of the plasma display panel of FIG. 2;

FIG. 5 is a plan view of the plasma display panel of FIG. 2 for illustrating a relation between the electrodes and ribs;

FIG. 6 is a plan view of the plasma display panel of FIG. 2 for illustrating a problem caused therein;

FIG. 7 is a diagram for illustrating a relation between a discharge starting voltage and a width of a tip part (an opposing edge part forming a discharge gap) of an ITO pattern in the plasma display panel of FIG. 2;

FIG. 8 is a diagram showing a structure of a plasma display panel according to a first embodiment of the present invention;

FIG. 9 is a diagram showing a structure of a plasma display panel according to a second embodiment of the present invention;

FIG. 10 is a diagram showing a structure of a plasma display panel according to a third embodiment of the present invention; and

FIG. 11 is a diagram showing a structure of a plasma display panel according to a fourth embodiment of the present invention.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

[Principle]

FIG. 7 is a diagram showing a relation between the width A of the tip part T_A of each ITO pattern XT or YT and a discharge starting voltage Vf, which relation is discovered with respect to the plasma display panel 11 by the inventors of the

present invention. In FIG. 7, the width g of each discharge gap is set to 100 μm.

According to FIG. 7, the discharge starting voltage Vf is almost constant at or below 200 V if the width A of the tip part T_A is greater than or equal to 150 μm, while the discharge starting voltage Vf rises sharply as the width A decreases in a region where the width A is smaller than 150 μm. Thus, the relation shown in FIG. 7 indicates that the width A of the tip part T_A must be set to 150 μm or greater to minimize the discharge starting voltage Vf. The width A can be smaller than 150 μm especially in such a case as shown in FIG. 6, but FIG. 7 shows that a discharge voltage is unavoidably increased in such a case. On the other hand, the discharge voltage can be decreased by decreasing the width g of the discharge gap to below 100 μm. In such a case, however, a discharge causes more damage to the tip part T_A, thus preventing the stable operation of the plasma display device 11.

A description will now be given, with reference to the accompanying drawings, of embodiments of the present invention.

[First embodiment]

FIG. 8 is a diagram showing a structure of a plasma display panel 21 according to a first embodiment of the present invention. In FIG. 8, the same elements as those described previously are referred to by the same numerals, and a description thereof will be omitted.

In FIG. 8, the plasma display panel 21 replaces the plasma display panel 11 in the plasma display device 10 of FIG. 1. Like the plasma display panel 11, the plasma display panel 21 includes the ITO discharge electrodes XT extending from the bus electrode x_1 toward the bus electrode

y_1 and the ITO discharge electrodes YT extending from the bus electrode y_1 toward the bus electrode x_1 so as to oppose the corresponding ITO discharge electrodes XT. The ITO discharge electrodes XT and YT are formed in the corresponding grooves G_1 through G_n separated by the ribs 11C.

Each of the discharge electrodes XT and YT includes the tip part T_A and the neck part T_B. In this embodiment, the width A of the tip part T_A is reduced from conventional 160 to 120 μm so as to secure a (positioning) margin of 90 μm between each discharge electrode XT or YT and the rib 11C adjacent thereto.

On the other hand, in this embodiment, in order to avoid the problem of the increase of the discharge voltage resulting from the reduction of the width A of the tip part T_A, the tip part T_A is defined by an oblique line part (edge part) T_a forming an angle θ with the bus electrode x_1 or y_1. For instance, by setting the angle (inclination) θ of the oblique line part T_a at 41°, the oblique line part T_a is allowed to have a length of 160 μm. The angle θ is preferably set at greater than 30°. However, if the angle θ is set at such a great angle that the oblique line part T_a has a length greater than 200 μm, a discharge current is increased while luminous efficacy is decreased. Therefore, the angle θ is preferably set at 60° or smaller.

In FIG. 8, the opposed discharge electrodes XT and YT extending from the bus electrodes x_1 and y_1 are disposed so that the oblique line parts T_a of the discharge electrodes XT and YT form a discharge gap of 100 μm in width.

By this structure, at the same time that the width A of the tip part T_A of each discharge electrode XT or YT is decreased, the tip part (edge

part) T_A where a discharge is actually caused can be ensured an optimum length or width that is greater than or equal to 150 μm and smaller than 200 μm. As a result, the problem of the increase of the discharge voltage and the accompanying increase of power consumption can be avoided.

[Second embodiment]

FIG. 9 is a diagram showing a structure of a plasma display panel 31 according to a second embodiment of the present invention. In FIG. 9, the same elements as those described previously are referred to by the same numerals, and a description thereof will be omitted.

According to FIG. 9, in this embodiment, in each of the grooves G_1 through G_n separated by the ribs 11C, the discharge electrodes XT and YT extend from both sides of the bus electrodes x_1 and y_1, respectively. Therefore, the same electrode arrangement of the discharge electrodes XT and YT as that formed between the bus electrodes x_1 and y_1 is formed between the bus electrode y_1 and the bus electrode x_2 adjacent thereto.

In the plasma display panel 31 of the above-described structure, a discharge can be also caused between the bus electrodes y_1 and x_2 as between the bus electrodes x_1 and y_1. Therefore, the plasma display panel 31 can offer resolution twice that of a structure formed by repeating the electrode structure of FIG. 8.

[Third embodiment]

FIG. 10 is a diagram showing a structure of a plasma display panel 41 according to a fourth embodiment of the present invention. In FIG. 10, the same elements as those described previously are referred to by the same numerals, and a description

thereof will be omitted.

According to FIG. 10, in this embodiment, each discharge electrode XT includes a discharge electrode XT_1 extending from the bus electrode x_1 in a first direction and a discharge electrode XT_2 extending from the bus electrode x_1 in a second direction opposite to the first direction. The discharge electrode XT_1 has a convex tip part T_A defined by oblique line parts T_b and T_c (forming an edge part of the discharge electrode XT_1), while the discharge electrode XT_2 has a concave tip part T_B defined by oblique line parts T_d and T_e (forming an edge part of the discharge electrode XT_2). Similarly, in this embodiment, each discharge electrode YT includes a discharge electrode YT_1 extending from the bus electrode y_1 toward the bus electrode x_1 and a discharge electrode YT_2 extending from the bus electrode y_1 in the opposite direction. The discharge electrode YT_1 has a convex tip part T_A defined by oblique line parts T_f and T_g (forming an edge part of the discharge electrode YT_1), while the discharge electrode YT_2 has a concave tip part T_B defined by oblique line parts T_h and T_i (forming an edge part of the discharge electrode YT_2). The same discharge electrodes are formed with respect to other bus electrodes not shown in the drawing.

The discharge electrodes XT_1, YT_1, XT_2, YT_2, … are formed along the groove G_1 defined by corresponding two of the ribs 11C and having the address electrode Z_1 formed therein. The discharge electrodes XT_1, YT_1, XT_2, YT_2, … are also formed in the adjacent groove G_2 but arranged in the reverse orientation.

In the structure shown in FIG. 10, the oblique line parts T_d and T_e of the discharge electrode XT_2 oppose the oblique line parts T_f and T_g of the discharge electrode YT_1, respectively, so

that a discharge gap of approximately 100 μm is formed almost evenly therebetween. Similarly, the oblique line parts T_b and T_c of the discharge electrode XT_1 oppose the oblique line parts T_h and T_i of the discharge electrode YT_2, respectively, so that a discharge gap of approximately 100 μm is formed almost evenly therebetween.

In the plasma display panel 41 of the above-described structure, by forming, by the oblique line parts, the edge part of each of the discharge electrodes XT_1, YT_1, XT_2, and YT_2 which edge part defines the discharge gap, the total length of the edge part with respect to the given width A of the tip part T_A can be made longer than in the above-described plasma display panel 21 or 31 whose discharge electrode XT or YT has its tip part T_A formed to have the single oblique line part T_a. This also indicates that, if the total length of the edge part of each of the discharge electrodes XT_1, YT_1, XT_2, and YT_2 is set to a value within 150 to 200 μm, for instance, to 160 μm, a larger positioning margin can be secured than in the above-described embodiments by making the width A narrower than in the above-described embodiments.

[Fourth embodiment]

FIG. 11 is a diagram showing a structure of a plasma display panel 61 according to a fourth embodiment of the present invention. In FIG. 11, the same elements as those described previously are referred to by the same numerals, and a description thereof will be omitted.

According to FIG. 11, the plasma display panel 61 of this embodiment is a variation of the plasma display panel 41 of FIG. 10, and the edge part of each discharge electrode XT which part forms a discharge gap together with an opposing one of the

discharge electrodes YT is defined by three oblique line parts a, b, and c. Similarly, the edge part of each discharge electrode YT which part forms a discharge gap together with an opposing one of the discharge electrodes XT is defined by three oblique line parts e, f, and g. This structure allows a discharge gap of approximately 100 μm to be formed almost evenly between each of the oblique line parts a and d, b and f, and c and g. If a patterning process permits, by providing each discharge electrode XT or YT with any complicated shape, it is possible to provide each discharge electrode XT or YT with an effective width of 160 μm while decreasing the width A of the tip part T_A.

In the above-described embodiments, the edge part of each discharge electrode has a width equal to or larger than 150 μm and a discharge gap of approximately 100 μm is formed between each pair of opposed discharge electrodes. However, these values are optimum values for the plasma display panels according to the present invention, and it is natural that these values should vary under different conditions of a material, a dielectric constant, a gas pressure, and a gas composition.

The present invention is not limited to the specifically disclosed embodiments, but variations and modifications may be made without departing from the scope of the present invention.

The present application is based on Japanese priority application No. 2000-266042 filed on September 1, 2000, the entire contents of which are hereby incorporated by reference.